Alternative Aviation Fuels Update – All Aboard!

Tim Edwards

AFRL Propulsion Directorate

Polar bears climbing onto jet fuel tanks in Canadian Arctic

AF Energy Plan (AFD 091208-028)

U.S. AIR FORCE

AIR FORCE RESEARCH LABORATORY

Alternative Fuels Evaluation

- Test F-T/JP-8 Blend
- Certify Fleet on F-T/JP-8 Blend
- Evaluate Biofuels for CO_2 Reduction
- Evaluate Pure Synthetic Fuels
- Material Compatibility

Acquisition & Technology 2016 Goals for R&D

- Reduce Demand—20% Increase in Lift-to-Drag Ratio
- Reduce Demand—Reduce Installed Specific Fuel Consumption by 25%
- Increase Availabilitiy—Certify Alternative Fuel for 50% of CONUS Consumption

Alternative Fuels Evaluation

- Test F-T/JP-8 Blend
- Certify Fleet on F-T/JP-8 Blend
- Evaluate Biofuels for CO_2 Reduction
- Evaluate Pure Synthetic Fuels
- Material Compatibility

Aircraft Technology

- Increase Aero Efficiency
  - Reduce Weight
  - Longer Range Missions
  - Increase Lift-to-Drag Ratio
- Advanced Light-Weight Materials

Efficient/Adaptive Engine Technologies

- Reduce Installed Specific Fuel Consumption
- Increase Thrust-to-Weight Ratio
- Improve Thermal Management

Advanced Design Systems

- Design Energy Conversion Systems to be Fuel-Flexible
- Pursue proactive partnerships with Energy Suppliers for Timely Deployment of New Technology

C-17 biofuel flight Aug 27, 2010

Alternative Fuel Evaluation (ASTM D4054, MIL-HDBK-510)

Specification Properties

Fit-For-Purpose Properties

Component/Rig Testing – operability, durability

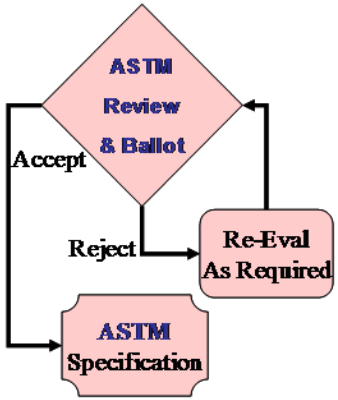
Engine/APU Testing

R&D

Cert.

ASTM Research Report

FAA & OEM Review & Approval



ASTM Balloting Process

ASTM D7566 Revision

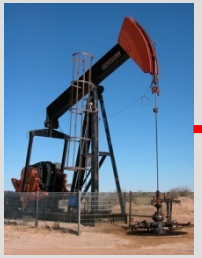
Alternative Fuels - Major Thrusts

- **High level goals:**
  - **2011 – 50/50 F-T blend certification for all systems (Alternative Fuel Certification Office (AFCO))**
  - **2016 – 50% of domestic consumption contains synthetics (F-T + ?) (~400M gal), "greener" than petroleum, cost-competitive**
- **AFRL**
  - **R&D planned jointly with CAAFI (Commercial Aviation Alternative Fuel Initiative)**
  - **Alternative aviation fuel certification support (properties, mat'l compatibility, rig testing, toxicol.) – bring candidates to TRL 5/6**
  - **Lifecycle Greenhouse Gas analyses**
- **Alternative Fuel Certification Office**
  - **2011 certification of 50/50 JP-8/F-T SPK (Fischer-Tropsch synthetic paraffinic kerosene from coal, biomass, nat. gas)**
  - **2013 certification of 50/50 JP-8/HRJ (hydroprocessed renewable jet from plant oils/animal fats)**

Synthetic Jet Fuels

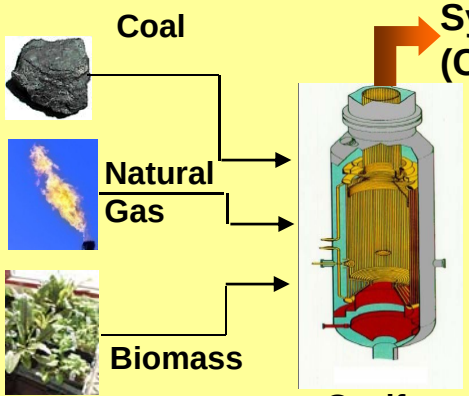
D 1655

Petroleum

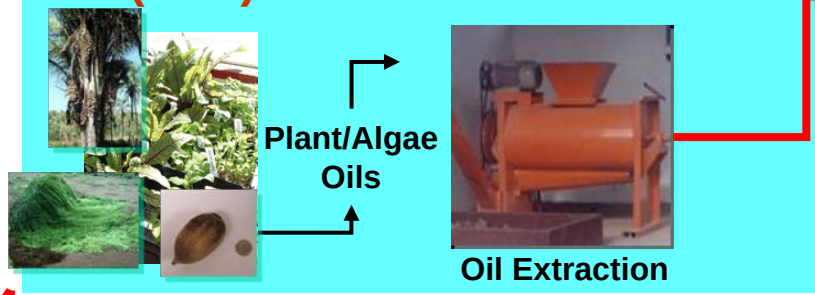


D 7566 Annex 1

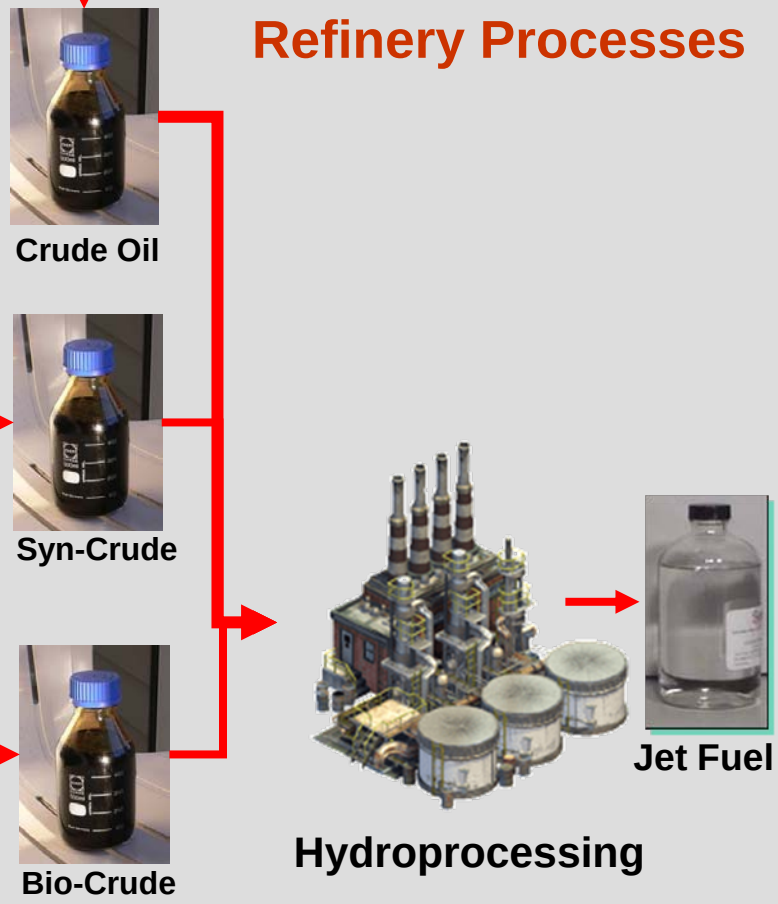
Fischer-Tropsch (FT)



Hydroprocessed Renewable Jet (HRJ) from Bio-Oils



Conventional Refinery Processes



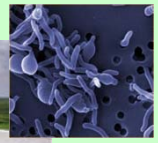
What's Next? Cellulosic Feedstocks and Fully Synthetic Fuels

U.S. AIR FORCE

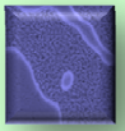
AIR FORCE RESEARCH LABORATORY

Advanced Fermentation

CO_2



Metabolically Engineered Microbes



Fermentation

Jet Fuel

Sugar

Alcohol Oligomerization

Fermentation

Dehydroxylate

Olefins

Conventional Refinery Processes

Polymerization

Jet Fuel

Lignocellulose

Pyrolysis

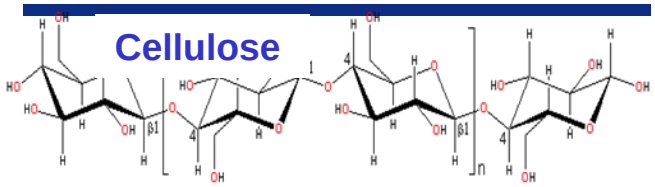
Pyrolysis

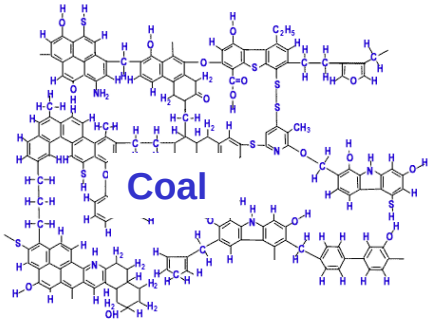
Bio-Crude

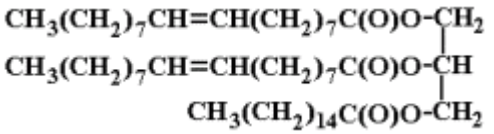
Hydroprocessing

Mark Rumizen FAA

Synthetic Jet Production Options



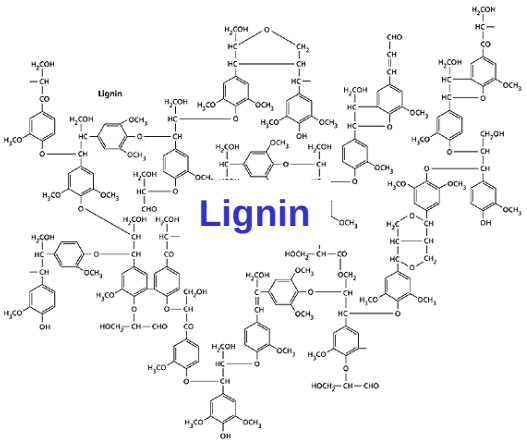




C16:1

C18:0

Triglycerides (fats, oils)



Lignin

gasification

pyrolysis

"HRJ"

"Bio SPK"

hydroprocessing

2

Fischer-Tropsch

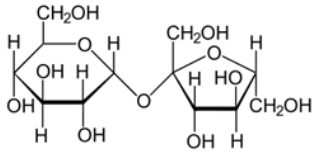
"BTL, CTL, GTL"

$CO + H_2$

1

alcohols

catalysis

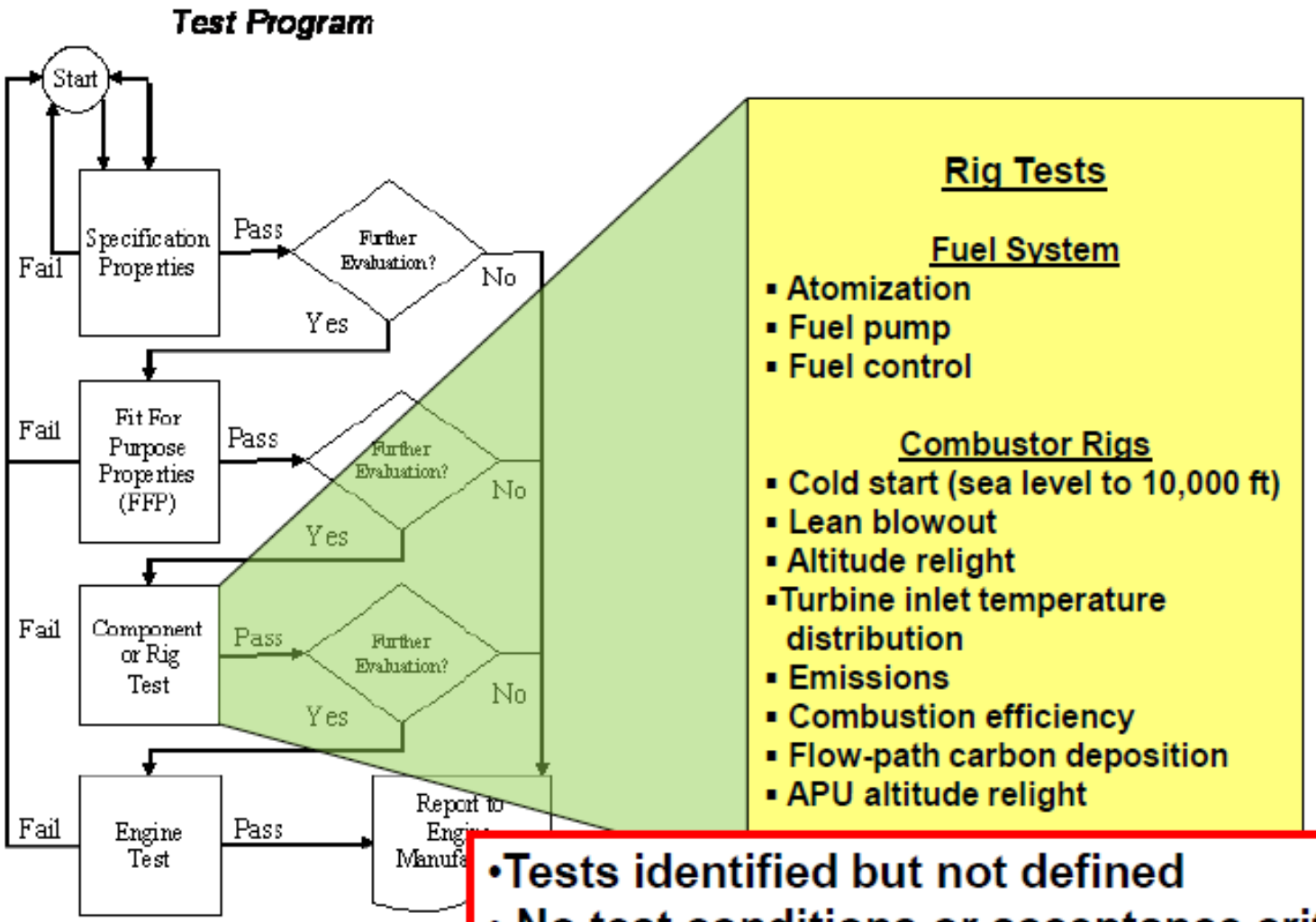


Sugars

"direct fermentation"

jet fuels/
components

Current Approval Process

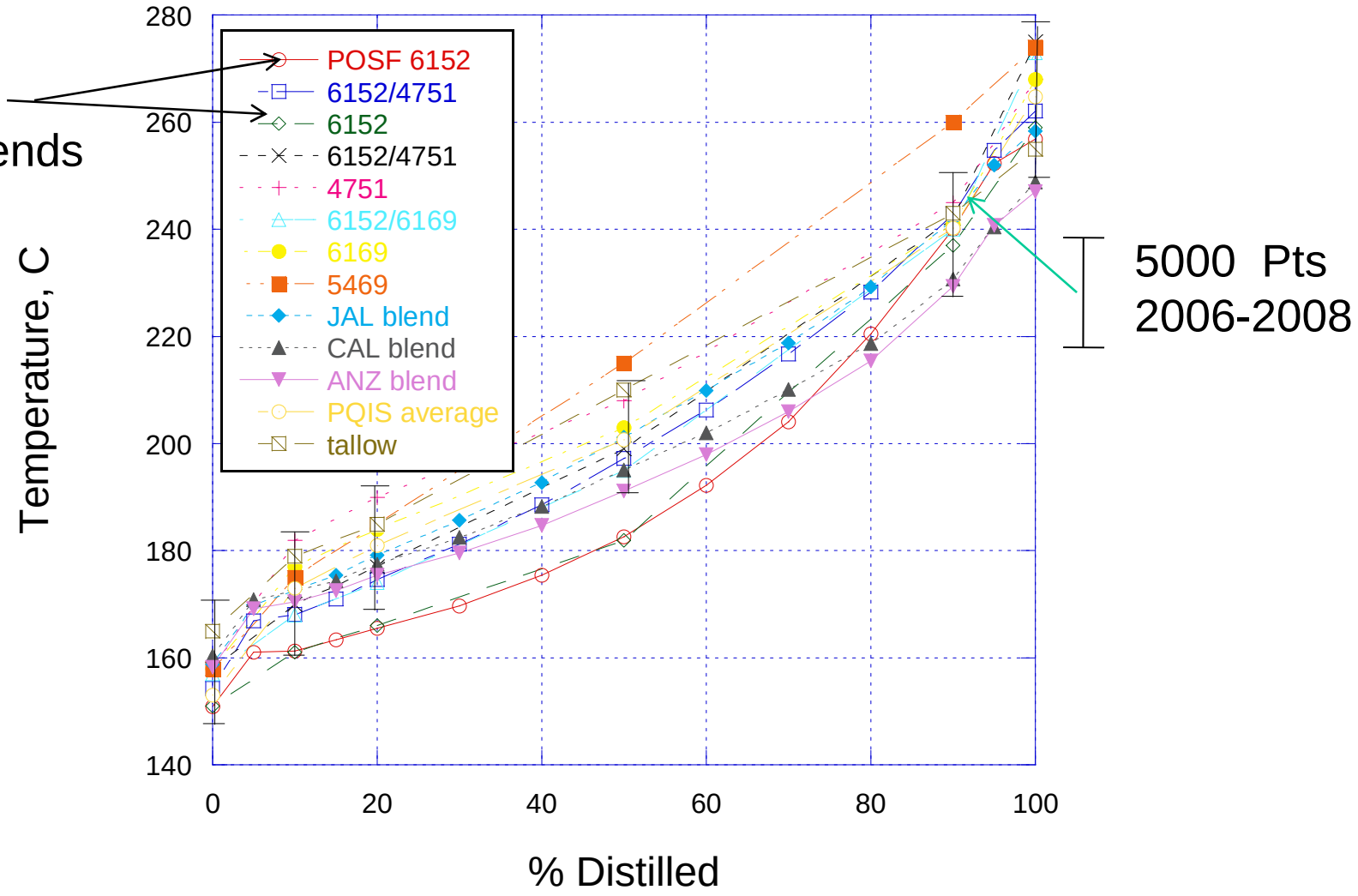


Reference Fuel Set

- **Category A** reference fuels are motivated by need to characterize fuel effects that are currently acceptable to the fleet within context of property distributions
  - Worst case JP-8 will set the boundary
  - Best case JP-8 will enable validation of proposed screening methodology
  - Nominal JP-8 will further add to our understanding of fuel property effects
- **Category B** reference fuels will provide an opportunity to using fuels in rigs that have recently failed and passed engine-level evaluations
  - Recommendations include FAME (failed) and Sasol fully synthetic fuel (passed)
- **Category C** fuels will provide final check on defined process by testing whether or not it will identify combustion effects due to property variation that is not currently covered by fuel specifications, and to provide data necessary to extend models into these domains

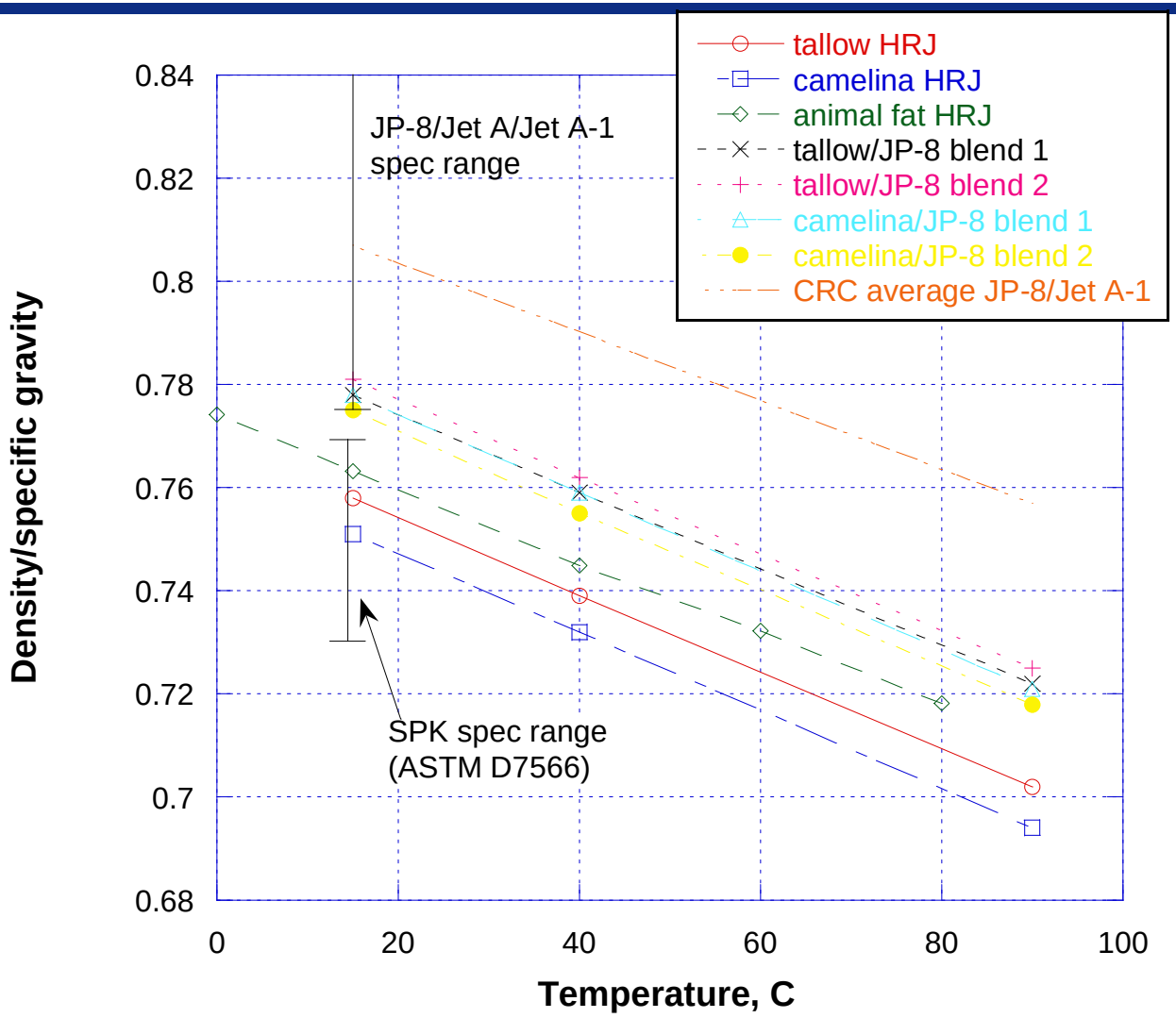
HRJ Distillation Data

AF HRJ blends



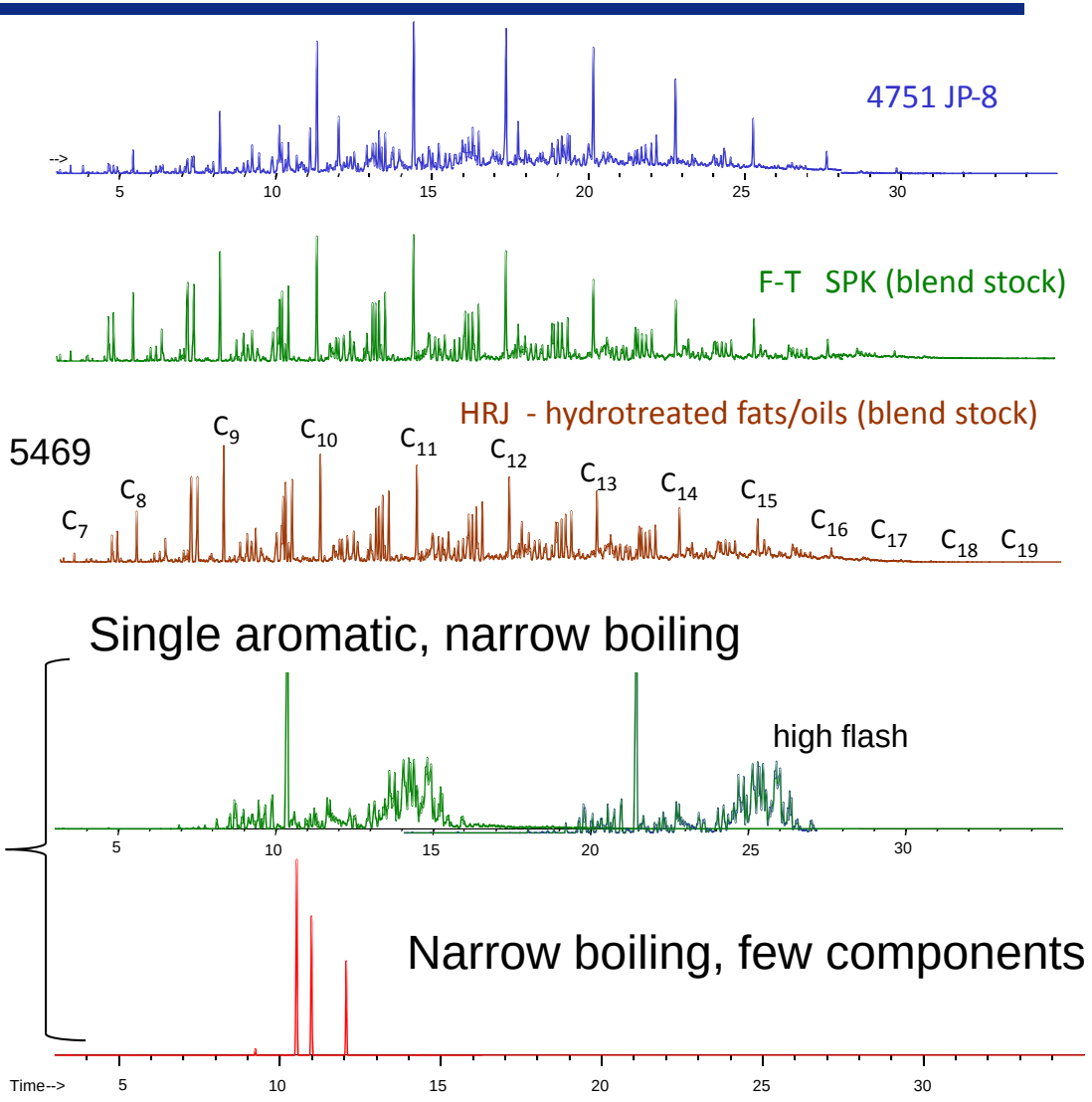
5000 Pts
2006-2008

Density vs T


tallow HRJ
camelina HRJ
animal fat HRJ
tallow/JP-8 blend 1
tallow/JP-8 blend 2
camelina/JP-8 blend 1
camelina/JP-8 blend 2
CRC average JP-8/Jet A-1
JP-8/Jet A/Jet A-1
spec range
SPK spec range
(ASTM D7566)
Density/specific gravity
0.84
0.82
0.8
0.78
0.76
0.74
0.72
0.7
0.68
0
20
40
60
80
100
Temperature, C

Category C Fuels for Program

- **Potential boundaries for cat C fuels:**
  - Max flash = 68 C?
  - T90- T10 < 22 C? (~4 C number spread)
  - Min aromatics <8%? (type of aromatics?)
  - 100% synthetic
  - Cycloparaffinic (high density)
  - ….



Potential fully-synthetic jet fuels

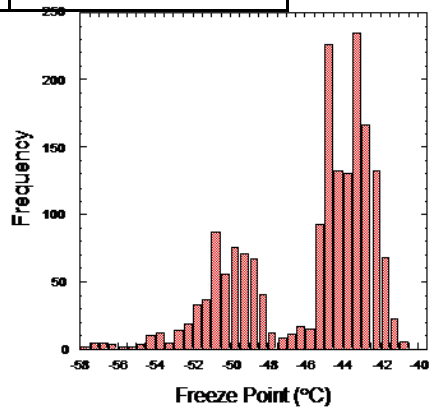
Results – Typical Jet Fuels

ASTM D2425

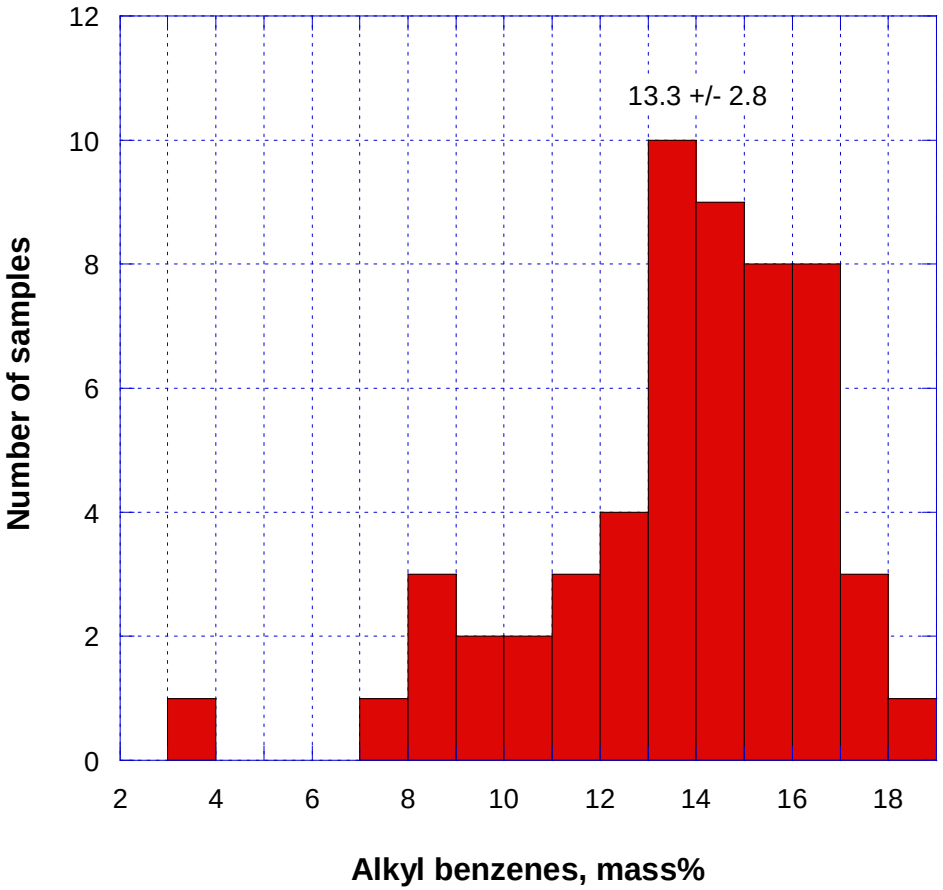
	World survey average, vol %	Composite Jet A blend (POSF-4658)
Paraffins (normal + iso)	53	52
monocycloparaffins	19	22
dicycloparaffins	8	6
tricycloparaffins	1	1
alkyl benzenes	13	12
indans+tetralins	4.6	4.9
naphthalene	0.1	<0.2
substituted naphthalenes	1.6	1.3

* The technique also measures acenaphthenes, acenaphthylenes, tricyclic aromatics, and indenes, but these were below detection limits in all cases.

Is Distribution “Normal”?



Compositional Distribution

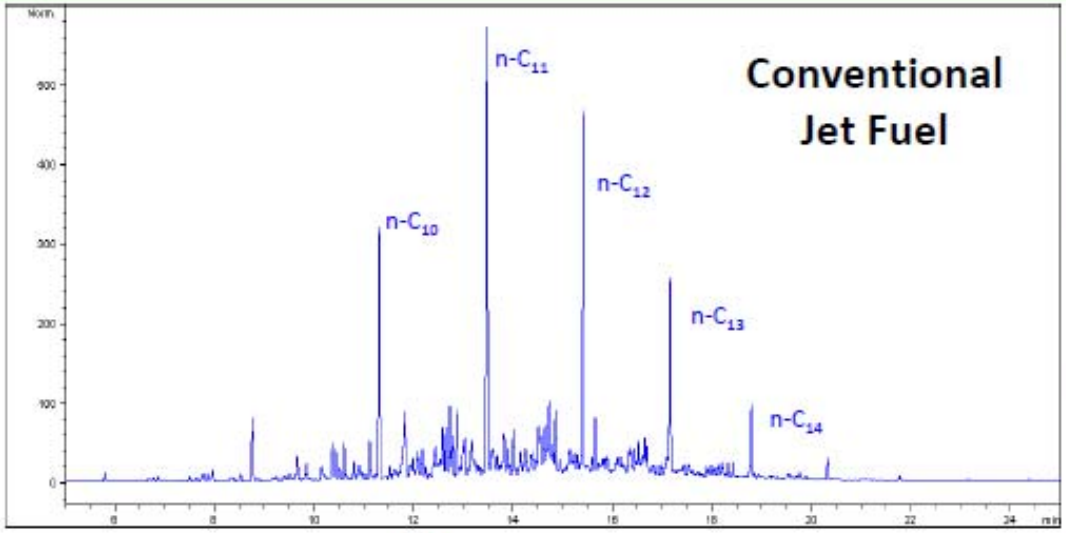


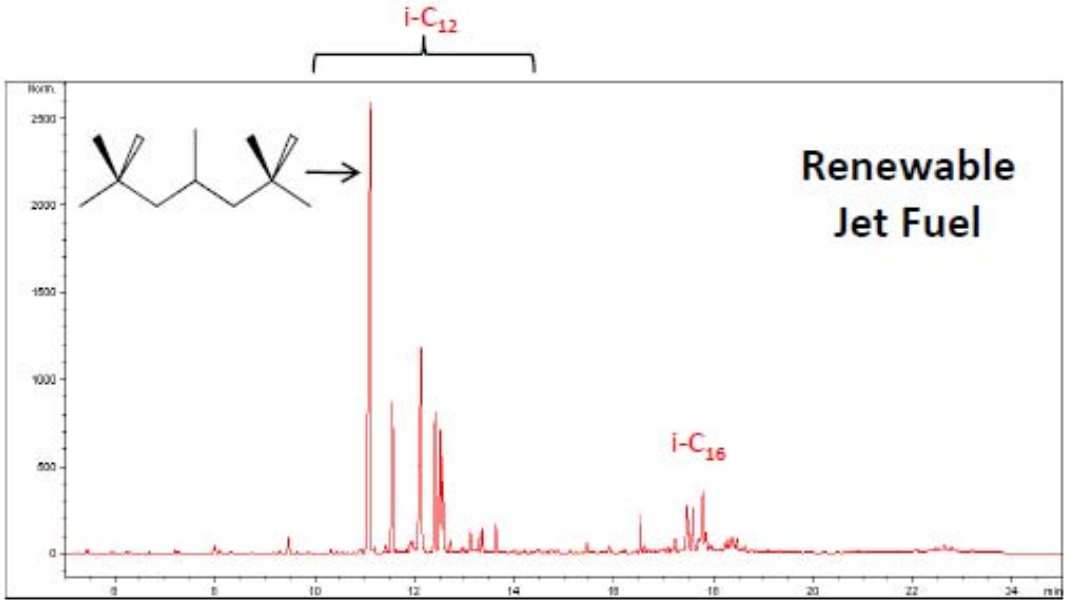
Alternative Fuel Composition

	6308 HRJ8-Tallow	6152 HRJ8-Camelina	4909 FT-SPK	6169 JP-8	4751 JP-8
D2425 (volume %)					
Paraffins (normal + iso)	98	90	97	59	50
Cycloparaffins	2	10	3	26	31
Alkylbenzenes	<0.3	<0.3	<0.3	10	12
Indans and Tetralins	<0.3	<0.3	<0.3	3.2	5.0
Indenes and C_nH_{2n-10}	<0.3	<0.3	<0.3	<0.3	0.6
Naphthalene	<0.3	<0.3	<0.3	<0.3	<0.3
Naphthalenes	<0.3	<0.3	<0.3	1.1	1.0
Acenaphthenes	<0.3	<0.3	<0.3	<0.3	<0.3
Acenaphthylenes	<0.3	<0.3	<0.3	<0.3	<0.3
Tricyclic Aromatics	<0.3	<0.3	<0.3	<0.3	<0.3
Total	100	100	100	100	100

Renewable Jet Fuel That Meets ASTM Specs

gevo



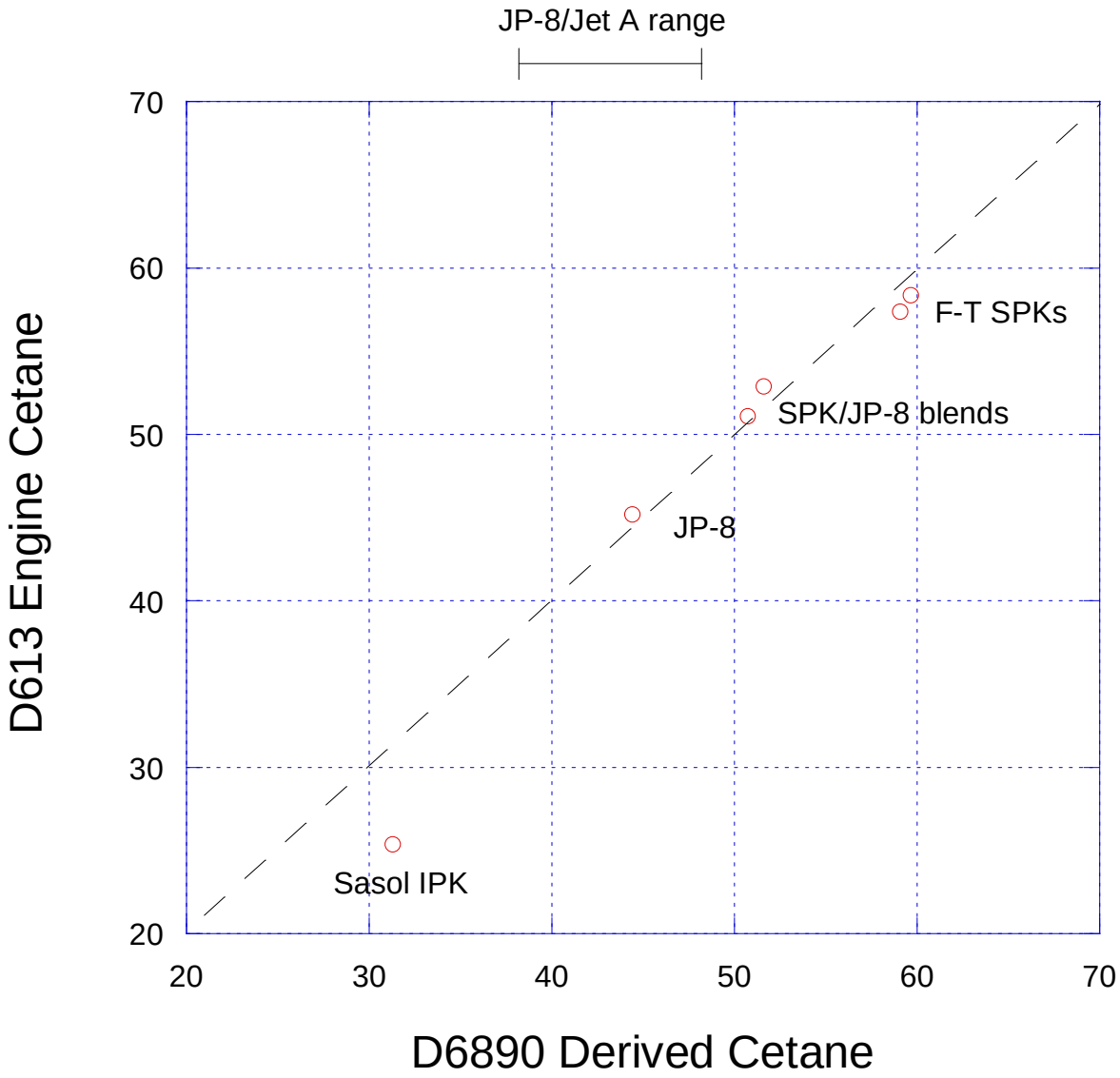


Specification	Conventional Jet "A" Fuel	Renewable Jet Fuel
Density at 15 °C (Kg/L)	0.775-0.840	0.770
Boiling Point (°C)	150-300	170-300
Flash Point (°C)	38	49
Freezing Point (°C)	-47	-81
Smoke Point (mm)	25	28
Lubricity, BOCLE (mm)	> 0.85	0.85

- Higher flash point
- Lower freezing point
- 100% renewable carbon
- Passed Tier 1 testing with the USAF
- Currently in Tier 2 testing

15

Combustion Effects of Composition



Preliminary WSR Blowout Data

Increasing cetane

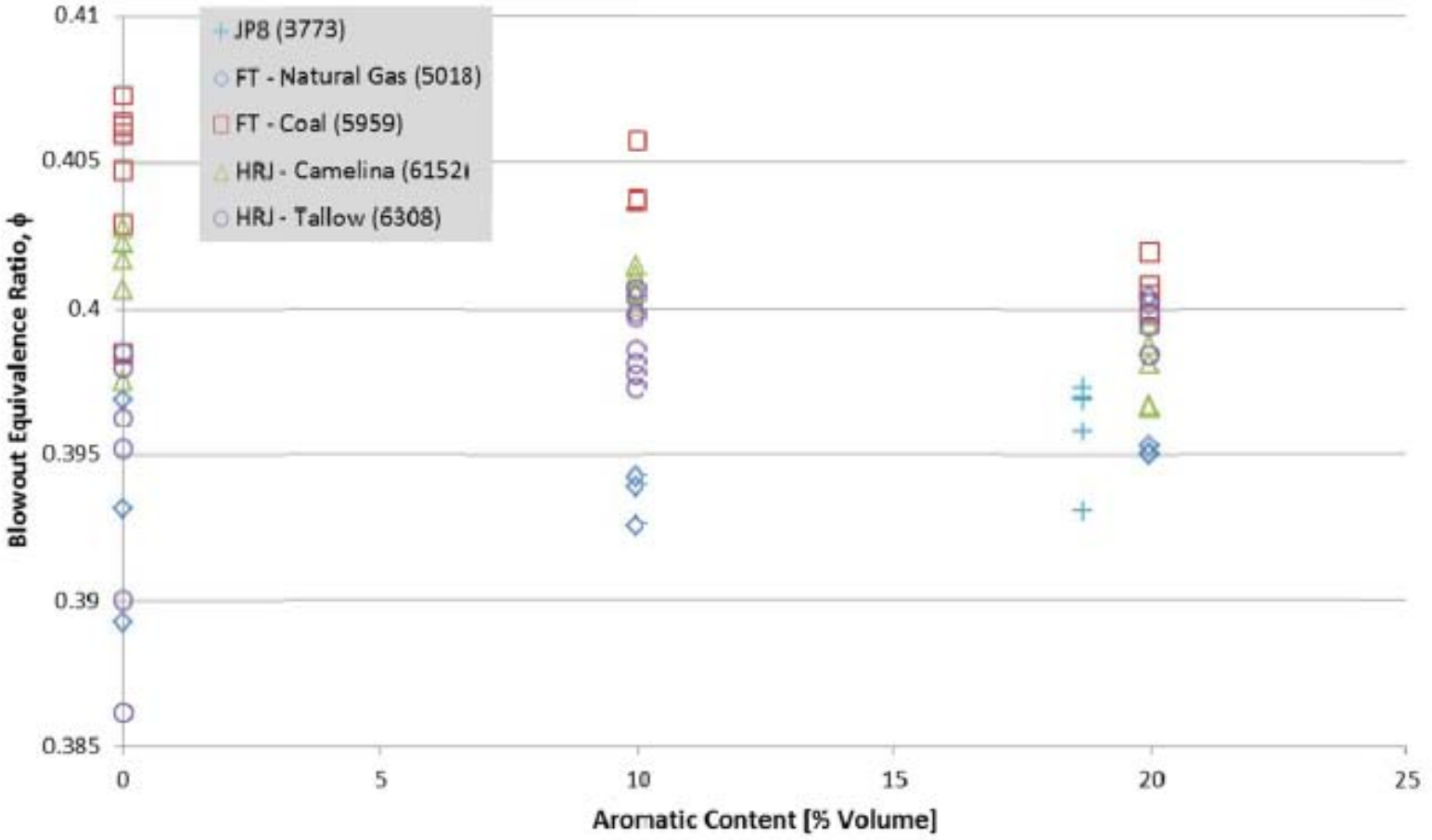


Figure 2. All Blowout Equivalence Ratios Versus Aromatic Content.

Assured Aerospace Fuels Research Facility (AAFRF)

- **Description:** Research facility to assess properties and performance of alternative jet fuels
- **Use:** Generate research quantities (15-25 gal/day) of alternative jet fuel
  - Evaluate properties to optimize specifications for new types of fuels
  - Evaluate processing, catalysis and feedstock influence on fuel properties
  - Evaluate processes to enhance production of alternative jet fuels
- **Status**
  - Upgrader installed and operational
  - Conditions being evaluated to produce “near spec limit” jet fuels

“Upgrader” in Bldg 490

Summary

- **Interest in alternative fuels remains high**
- **Biomass-derived fuels are current S&T focus**
  - **“Drop-in” petroleum replacements/blendstocks are focus in near term – fully synthetic in mid term**
  - **Seeking authority for AFCO to work beyond HRJ**